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# Paradigm of a New Type of Engineer Training in Earth Sciences

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**Abstract.** This paper attempts to define key trends observed in new-generation mining engineer training today. A comparative analysis, which looked at recent developments in teaching concerned with innovative technology and transformation of scientific knowledge in general, indicates the need for a new educational paradigm. Actual interaction between humans and their environment was taken as a hypothesis about professional knowledge and skills. The role of the axiological components of the new paradigm was revealed in the light of the communication nature of the society. A methodology was developed to build a new-generation engineer model. The paper reveals the role of a learner's metacognitive ability in the development of new teaching techniques. The paper highlights how important it is that an engineer was striving for environmentally friendly technology. The authors defined the effect of the altered environment on engineering. The paper substantiates why one can only be said to have hard & soft skills if one is able to apply critical and creative thinking. It was found that training an engineer under the new paradigm is inevitably related to the ability to reflect. Analysis of the linguistic modality serves to support this statement.

## 1. Introduction

One of the features of the globalized society includes a complex integrative process created by intersecting regularities of the natural and social worlds. A drastically increasing human impact on nature makes it even worse in terms of the interaction between humans and the environment. The 20<sup>th</sup> century was marked with an actual four-fold rise in the global population, which resulted in an 18-times higher production output. Because of that, the Global Footprint Network (GFN) has to constantly change the date of the Earth Overshoot Day moving it every time closer. This way it simulates the situation when the humanity's resource consumption for the year exceeds Earth's capacity to regenerate those resources that year. Experts compare the humanity's ecological footprint (i.e. the consumption of renewable resources by humans) to biocapacity (i.e. Earth's capacity to regenerate itself and absorb waste, including CO<sub>2</sub>). The resources consumption rate rises year after year and the Earth Overshoot Day moves closer and closer. In 2014 it was on 19 August, whereas in the early 2000s – in October [1]. Consequently, the world needs a new generation of engineers who



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would be capable to adequately respond to the environmental challenges. An indirect proof of the need to reconsider the current engineer training system is a strong shift of emphasis in the theoretical analysis of human capital – a concept that encompasses both labour and production markets and the environmental status. Thus, according to the timeline of counterfactual nodes, instead of looking at conventional statistics on education, mobility, healthcare as professional efficiency criteria, one should be monitoring the changes in their controversy for proper correlation of market demands and the available human capital [2]. As the mentioned transformations in the humans-environment interaction raise the status of Earth sciences and, considering rising trends towards cross-disciplinary research in science, make them universal, the new engineer training paradigm manifests itself most vividly in professional training in these academic areas.

## 2. Materials and methods

Academic papers by the following authors are to be noted in this regard: R.Azevedo[3], J.R.Harris, R. Galvin [4], O.E. Gorlova, I.V.Shadrunkova, T.V.Chekushina[6], V.A.Zhilina [6,7,14], S.Biswas, S.Ghosh, R.Halder [8], V.E. Kononov [11], M.Develaki [12], A.S.Aldossari [13], N. V.Kuznetsova [14,19], S.N.Barringer, E. Leahey, K. Salazar [15], J.B. Main, B.N Johnson, Y. Wang [16], C.Wang, Y.Zhang, J.D.Moss [17], R.Tytler, V. Prain, S.Hannigan [18], Y.Jang, H.Lee, Y.Kim [20]. Overall advancements in scientific research in such areas as educational psychology, cognitive psychology, developmental psychology, cognitive sciences, pedagogical sciences, STEM education and a new approach to knowledge systematization in Earth sciences determine the need for a cross-disciplinary approach to the problem in view. Correspondingly, the core methodology is based on the philosophical principles of from the abstract to the concrete, the cohesion between the historical and the logical, and the consistency principle. A simulation technique was applied to analyze the difference in learners' metacognitive knowledge and skills, as well as declarative and procedural metacognitive knowledge [3]. Classification of the key elements of the new training paradigm enables to define the axiological component, the new ontological basis and the theoretical model of a new-generation engineer as the conventional bifurcation points. A synergy-based approach appears to be most relevant considering this is cross-disciplinary research.

## 3. Results and discussion

### 3.1. A basis for the new-generation Earth sciences engineer training paradigm

At all times, professional engineer training has aimed to shape a certain type of rational thinking and build the skill of utilizing the acquired knowledge. A specific feature of today's engineer training system is that the way one explores the reality with the help of one's rationality has been undergoing a fundamental transformation. Beside the fact that the subject-object interaction does not follow the classical path of scientific development and, consequently, has to also rely on the irrational, the conventional principles behind conceptual perception of nature have also seen an essential transformation. Thus, more and more researchers who look at the logic of scientific knowledge speak of the so-called 'casual impotence'. This reflects another transformation of the fundamental principle of rationality – the causality principle [4]. In ontological substantiation, the work of a would-be Earth scientist is determined by a contradiction inherent in the time characteristic of the environment. At the current rate of mining, processing and waste generation, the humanity is estimated to spread nearly all the Periodic Table elements over a time period of less than 15,000 years of its existence, while nature needed the entire period of the Earth's geological history – i.e. more than 4.5 billion years, to reaccumulate the elements in the crust [5]. Therefore, the new engineer training paradigm should be based on the principle of anthropogenic metabolism between humans and nature, which implies that a new-generation engineer should be trained to recognize the fact that humans as a strong biological species are inseparable from their habitat. An innovative feature includes bringing all specialist disciplines into compliance with the law of a real cohesion between how humans treat the environment today and are likely to treat it in the future. If the existing concept of a professional engineer's

qualification is exclusively based on the principle of prospective interaction with the environment – the environment determines if one's needs can be satisfied, the regularities characteristic of today's altered environment indicate that this assumption would not be satisfying. Depletion of natural resources is primarily about the quality. Once extracted, elements do not entirely disappear but rather get dispersed [6-9]. The way humans treat the environment today has a more sophisticated nature: treating the habitat like animals do cannot be sufficient for humans, the natural environment as it is cannot satisfy their needs, therefore the environment needs to be transformed. Then the fundamental difference of the new Earth specialist training paradigm is as follows: What serves to integrate the knowledge delivered by specialist disciplines in the current training system is the provision stating that a human being is a living creature and he/she depends on the habitat to survive. Consequently, all relevant disciplines focus on understanding the essential laws of the habitat independent of the human evolution and aim to teach how to design techniques for simple exploitation of nature. In the new paradigm, it is the need that becomes the key aspect integrating the acquired knowledge with the hard skills that are built on the basis of such knowledge: a human being is a combination of his/her needs, and the environment in this case is a combination of objects that can satisfy such needs. This new fundamental principle that forms the basis of the new engineer training paradigm will absolutely shift the focus of the developed environmental transformation techniques. The engineer of the nearest future will have to develop and use environmentally friendly techniques only. Through feedback, the Earth sciences will have a different object of study: the environment is not just an inert source of wealth but a complex and dynamic system that also incorporates humans with their social status. This directly lowers the risks of geo- and biodegradation.

### *3.2. Axiological component in the new-generation Earth sciences engineer training paradigm*

The axiological component of the new engineer training paradigm is related to the fact that the future engineer is forced to deal with the situation of a metabolic gap between humans and their habitat. Besides, what adds to this traditional discrepancy between the social and natural exchange today is that the binding component – i.e. production – becomes equal to natural laws in defining the environmental evolution. While creating an alternative environment, industrial production is still governed by the natural metabolism laws. That's why in practice the current production techniques cannot be adapted to the altered environment. Consequently, a new-generation engineer should know the classical theory of natural laws but should only apply this knowledge through the ability to establish an equal law with his/her work. What one may consider to be the factor that entailed the new training paradigm is the concepts of industrial metabolism which are in the focus of today's engineering science. It is partially related to the mathematization trends observed in certain disciplines of the Earth sciences [10].

The axiological component of the new paradigm is much wider than the environmental factor. It is defined by the logic behind the evolution of the Earth sciences in terms of their practical application in industry. Thus, mining landscaping determines the need for beautification skills that a new-generation mining engineer should possess. An aggressive landscape typical of mining sites, which is basically a combination of buildings with numerous stacks, roads, pits, mines and supporting structures, overburden dumps, tailings ponds and slurry pits, mountains of dumped slag and ash, etc., reminds of 'exclusion zones' or 'wasteland' or 'industrial desert' [11]. This beautification skill included in the mining engineer training paradigm has basically nothing to do with beauty but directly refers to professional knowledge. The future engineer should be able to simulate possible changes in the Earth ecosystems (such as litho-, hydro-, phyto- and zoospheres) and their possible impact on the atmosphere. In the area of industrial deposits, a new-generation engineer should be able to design innovative techniques which would be close to the natural circulation of elements. Thus, it is not depleting the nature's wealth but converting resources into renewables that is the focus of the new training paradigm. In this sense, the changed axiological component in the new-generation mining engineer training paradigm conforms to the needs of the altered environment, which sees a constantly growing amount of man-altered ores. Academic education should be aimed at building predictive

analysis skills to make the future engineer capable of analyzing the chemical elements as they begin to actively migrate into the environment in the form of ions as a result of mining operations. The future mining engineer will be able to potentially prevent the formation of geochemical anomalies in the Earth crust that would have significantly higher concentrations of certain chemical elements or their compounds compared with the background concentrations which are the result of ore mining and concentration operations. That's why the axiological component of the new training paradigm is mathematized. In line with the integrated STEAM education, it is necessary to teach learners universal simulation skills [12]. In its turn, the engineer's work will be universally integrated with the general Earth status system becoming more and more akin to the laws of nature. This can be proved by that safety analysis would not be confined to minimizing external threats but it will capture an integrated system Man – World. The engineer trained in the new paradigm will be able to evaluate a hazard not just on the basis of toxic element concentration but also judging by the status of man-environment exchange.

### *3.3. Superengineer as a universal creative innovator*

In the altered social environment, a country's competitiveness is, like before, determined by how efficiently it exploits the environment. However, multiplying the existing processing techniques cannot be satisfactory in today's reality. Environmentally friendly technology is designed to minimize the risk of destruction related to the engineer's work. What differentiates this type of approach is not that this technology can offer fundamentally different engineering solutions but that it can infiltrate all business spheres. That is the very reason that the concept of integrated hard & soft skills, which is being constructed in education, makes it necessary that mining engineers were taught basic economic, financial and communication skills. The new paradigm inevitably absorbs new determination trends in environmental evolution. The factor that conceals the actual problem of the man-environment relationship today includes the use value being substituted with exchange value amid developing capitalism.

Both real life and theoretical research in the area of higher engineering education indicate the lack of efficiency of the current training paradigm. Many graduates lack the required qualifications to be competitive at the labour market, and there is a clear disparity between the quality and amount of professional knowledge generated by education and the professional structure required by economics [13]. Therefore, the new paradigm should make a fundamental difference by changing the way skills are selected to teach students the basic theory in professional areas. Besides, the new paradigm should as much as possible close the gap between training of mining engineers and the reality related to employment opportunities and incentives after TVET [13]. For a future professional to be flexible and respond to changes in all markets – from labour market to economic situation, educational standards should evolve to become something different than just a sum of a certain number of disciplines. It means that conventional learning of separate technical disciplines with an additional fragmental knowledge of humanities cannot build a real system of hard & soft skills [14].

In this aspect, the proposed paradigm of training a mining engineer of the future can be defined as a system of training a superengineer whose professional qualifications are directly defined by the degree of practical application of his/her engineering and academic knowledge in his/her work. This suggests that changes are necessary in the institutional development of Earth sciences. First of all, universities themselves should intensify their involvement in cross-disciplinary research. The number of doctoral degrees awarded and R&D costs should serve as the criterion of real and not just formal research initiatives, in which future engineers should be involved from the start [15]. Collaboration between universities in the learning and teaching process should be decomposed to cooperatives aimed at giving students an early practical experience by alternating full employment with conventional classroom learning [16]. The available data suggest that members of a cooperative are, on average, more likely to win engineering positions and earn higher starting wages than their fellow colleagues who do not participate in a cooperative [16].

#### 4. Conclusions

Development of an essentially different paradigm for training mining engineers was dictated by a new paradigm of scientific knowledge. For multiple reasons (both of social and scientific nature), science serves as an integrator of knowledge that belongs to different areas. And the cross-disciplinary approach is aimed at reconstructing the man-environment interaction. Satisfying the needs of the society at the stage of production and communication digitalization, the new engineer training paradigm is focused on the historical cohesion between humans and their environment. What should serve as a kind of ontological basis for the development of new trends in engineer training is the idea that human existence basically stands for interaction with the environment for the purposes of protection and survival. This imparts a principally different status to Earth sciences, and, consequently, an engineer's work should acquire meaning. Even today one can observe the semantic borders of the profession being demolished. Thus, unconstrained and intensive exploitation of natural resources (nature's wealth) is no longer unquestionably regarded as a professionalism criterion. The engineer of the future is not fighting against the depletion of resources or pointing out an increasing degradation of nature as a result of loss of inherent properties. The engineer of the future is free from considering conventional environmental issues. By performing his/her work, an engineer rises above the global degradation of the Earth's geo- and biospheres.

The study shows that, apart from adopting a fundamentally different approach to developing environmental transformation techniques, a future Earth scientist should know how to handle information. In the altered environment, an engineer's efficiency is directly governed by his/her ability to transfer knowledge and apply it in a particular situation [17]. Today's multilingual culture and learners' immersion in languages adds to the challenges of today's professional training. On the other hand, some researchers fairly underline the fact that linguistic multimodality helps boost students' motivation, expands students' perception in inquiry-based learning and develops creative thinking [18]. In an engineer's practical work, the latter enables to professionally demarcate scientific solutions from pseudoscientific ones. In terms of theoretical substantiation of the new engineer training paradigm, the use of language techniques belongs to the sphere of metacognition learning [19]. It has been recently suggested that a learner's metacognition skills should be used as an academic performance criterion [20]. Through application of metacognition learning, the new engineer training paradigm can be adjusted to fit self-regulated learning paths [3].

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